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Description

Substrate for an organic field effect transistor, use of said substrate, method of increasing the charge carrier mobility and organic field effect transistor (OFET)

The invention relates to a substrate for an organic field effect transistor, to the use of said substrate, to a method of increasing the charge carrier mobility and to an organic field effect transistor onto which an organic functional material can be deposited in the form of a well-ordered layer.

When fabricating electric circuits based on organic materials, as in the case of organic diodes, condensers and, in particular, organic field effect transistors (OFETs) for example, thin layers of an organic functional material are applied to suitable substrates of silicon, glass or plastics material by various methods, such as spin-coating, knife coating, spraying, plotting, printing, vapor deposition, sputtering, *etc.*. In order to obtain favorable material characteristics conducive to good electrical performance, *ie* characteristics such as high electrical conductivity or a high charge carrier mobility, it is advantageous to produce a certain degree of molecular orderliness in the organic functional material.

In the literature there are described simple substrates of silicon [Z. Bao *et al.*, Appl. Phys. Lett. 69 (26) (1996) 4108]; polycarbonate [G.H. Gelinck *et al.*, Appl. Phys. Lett. 77 (10) (2000) 1487] or polyimide [C.J. Drury *et al.*, Appl. Phys. Lett. 73 (1) (1998) 108], and, in addition, mechanically pretreated, *ie* brushed polyimide substrates, which facilitate a well-ordered deposition of conjugated polymers as semiconductors and thus lead to higher field effects in OFETs compared with unprocessed polyimide [H. Sirringhaus *et al.*, Science 290 (2000) 2123]. Mechanical pretreatment is cost-intensive, *ie* it involves an additional processing step and can cause damage to the surface of the substrate.

US 2002041427 discloses a process for the production of a crystalline, nonlinear optical (NLO) film, in which the well-ordered application of the NLO film is facilitated by means of an intermediate layer (alignment layer) applied just for this purpose.

Except for these attempts to facilitate a well-ordered application of a functional material and/or to guarantee the same to a certain degree, there is as yet no method of applying a functional material to a substrate in an orderly fashion. However, the well-ordered application of an organic functional material is a decisive factor influencing the charge carrier mobility thereof. Thus there is a constant need to provide methods by means of which layers of functional material can be produced that are better ordered.

It is thus an object of the present invention to provide a substrate or an undersurface, which has a well-ordered surface allowing the application/deposition of an oriented and well-ordered organic functional material.

The present invention relates to a substrate and/or underlayer of an electronic component, which substrate or underlayer is to be coated with an organic functional layer, wherein said substrate or underlayer comprises an oriented, stretched (well-ordered) plastics film such that the orderliness of the plastics film enables the application of the functional material in the form of a well-ordered layer.

By substrate, undersurface or underlayer is meant in this case any layer that can serve as a carrier for a layer containing organic functional material. It can, of course, be a film used for encapsulation, such as when an OFET is fabricated in bottom-up layout.

The term "organic material" or "functional material" or "(functional) polymer" includes in this case all types of organic, organometallic, and/or organic-inorganic man-made materials (hybrids), particularly those referred to in the English language as, *eg*, "plastics". All types of materials are suitable with the exception of the semiconductors forming classical diodes (germanium, silicon) and the typical metallic conductors. It is thus not intended to dogmatically confine organic material to that consisting of purely carbonaceous material, but rather the term also covers the wide use of, say, silicones. Furthermore, the term should not, with respect to molecular size, be particularly confined to polymeric and/or oligomeric materials but can also refer to the use of "small molecules". The word component "polymer" in the term "functional polymer" is of historical origin and contains no inference to the presence of an actual polymeric compound.

Preference is given to the use of an axially stretched oriented and/or at least partially crystalline plastics film, particularly a monoaxially and preferably a biaxially stretched plastics film. For example, a suitable film is one of isotactic polypropylene, polyamide, polyethylene, polyethylene terephthalate, polyphthalamide, polyethylene, polyether ketone ketone (PEKK), polyether ether ketone (PEEK), syndiotactic polystyrene, polyvinylidene difluoride, polytetrafluoroethylene, *etc.*.

Due to the fact that the polymer films are stretched during manufacture and subsequent processing thereof, some of the crystallites formed in the substrate and thus also on its surface are highly ordered and assume the form of parallel molecular chains or chain portions which make it possible to deposit, as well-ordered layers, conjugated polymers and also organic materials of lower molecular weight (monomers, oligomers and/or "small molecules") in conducting and non-conducting forms as well as in semiconducting and non-semiconducting forms. Application of the said organic functional layer can be carried out from solution (spin-coating, printing, immersion, knife coating *etc.*) or alternatively from the vapor phase (vapor deposition, sputtering *etc.*). The orientation of the substrate allows it to serve as a so-called "alignment template" and leads to the formation of highly ordered areas in the precipitated functional material, which leads to higher conductivity and/or higher charge carrier mobility.

The invention is explained below with reference to a Figure.

This shows a substrate 1, preferably a biaxially stretched plastics film, for example a film of polyethylene terephthalate (PET), which supports the source and drain electrodes 2 (of, for example, conductive polyaniline (PANI)). The semiconducting layer 3 is applied to the substrate such that it is deposited in direct contact with the biaxially stretched plastics film 1. Thus a well-ordered state is produced within the semiconducting layer, by means of which better mobility of the charge carrier is attained. For this purpose a solution of poly(3-hexylthiophene) in chloroform, for example, is applied by spin-coating to substrate 1 so as to form a homogeneous polymeric layer having a thickness of 100 nm. Following a drying step, an electrically insulating polystyrene layer 4 is applied by spin-coating to form the gate dielectric.

Production of the gate electrode 5 is effected in a manner well known to the person skilled in the art (sputtering *etc.*).

An organic field effect transistor (OFET) applied in this manner to a substrate which has been pre-oriented by stretching shows a charge carrier mobility of $\mu > 10^{-3}$ cm^2/Vs. This value is several orders of magnitude higher than the mobility possible in OFETs of identical structure but having a non-oriented substrate, *eg*, one of silicon or silicon dioxide.

The invention makes it possible, for the first time, to increase the charge carrier mobility in organic semi-conductors by several orders of magnitude due to the selection of a suitable substrate.